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Novel Fabrication of Surface Plasmon Resonance Fiber Probes Using Water-Assisted Peel-off and Scoop-up Method

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Abstract

We demonstrate a novel fabrication method to make optical fiber sensing probes with the end face of each optical fiber patterned with submicron scale Au hole-array using a novel peel-off and scoop-up method.

1. Introduction

Sensors based on surface plasmon resonance (SPR) with label-free, real-time detection have been developed for biomolecule binding events [1]. Integrated with measurement system, glass is generally used as substrate to fabricate the SPR sensors. The angle-dependent Kretschmann configuration requires complex optical setup to couple incoming light to metal film/environment surface [2]. Instead, the periodic metallic nanostructure can be implemented to couple normal incident light to surface plasmon polaritons (SPPs), which has proven to be a simple and easy to use alternative [3]. Optical fiber sensors offer the advantages of system miniaturization, optical alignment-free and remote sensing [4]. These features have continually motivated research towards Lab on Fiber technology. Quite a few techniques have been reported to transfer nanostructures realized on planar substrates to fiber tips. Though electron-beam lithography [5] or focused ion beam milling [6] can directly define the structure on an individual fiber end, they often involve complex equipment and the patterning processes are generally time consuming. To increase the fabrication yield, a hybrid technique was reported by Lipomi et al., who used an ultra-microtome equipped with a diamond knife to manually transfer arrays of gold nanostructures embedded in thin epoxy slabs to the fiber tip [7]. Nano-transfer printing (nTP) is a promising technique to directly transfer metallic films to a non-planar surface [8] or a fiber end [9]. In this work, we demonstrate a novel and simple fabrication method by combining interference lithography (IL), water assisted peel-off process and scoop-up process. The scoop-up method was reported by Kim, Keun Soo, et al., to transfer grapheme films to arbitrary substrates [10], and by Kim, Jae-Han, et al., to transfer Au film onto water surface [11]. We demonstrated a large-area and high uniformity metallic nanostructures fabricated on a glass substrate to excite SPPs. Compared to epoxy transferring and nano-Transfer Printing method, the peel-off and scoop-up process avoids time consuming and crack causing procedures.

2. Experimental results

Two dimension hole-arrays with period of 500nm were fabricated by employing double-exposure IL as schematically shown in Fig. 1(a). Thanks to Lift-off Resist (LOR), undercut structure were created during development procedure. A 50nm Au layer was deposited by e-beam evaporation as shown in Fig. 1(b). Because of lift-off processes, the Au film could be easily peeled off from the substrate and made afloat in acetone solution, as depicted in Fig. 1(c). For preliminary testing, Au nano-structured film was then transferred onto a glass chip by a scoop-up process as shown in Fig. 1(d-1). For reflection type sensing, we transferred Au nano-structured film onto fiber ends which packaged in a fiber bundle, as shown in Fig. 1(d-2).

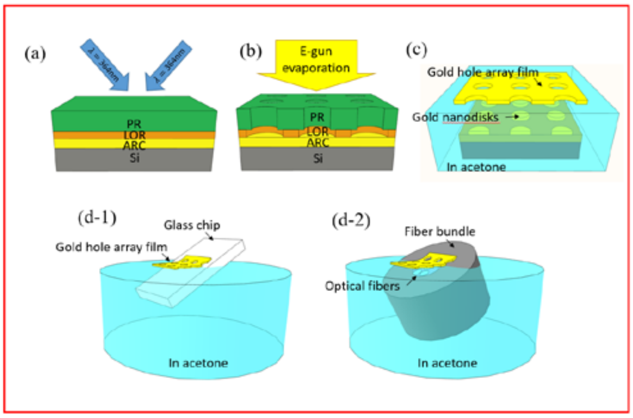

Fig. 1 Fabrication process of making SPR sensors on a glass substrate or fiber ends.

Photoresist and LOR were used as a sacrificial layer to enable the subsequent water-assisted peel-off. Fig. 2(a) shows the ultra-thin Au film is floating in acetone solution, and Fig. 2(b) shows the film is being scooped up. In Fig. 2(c), diffracted light can be seen from the hole-array structure, indicating the Au film with good uniformity. Fig. 2(d) shows a scanning electron microscope (SEM) image of the hole-array pattern and a magnified image. In Fig. 3, the leading experiment shows the measured transmission spectra of the glass chip, which confirms the uniformity of the pattern among nine measurement spots over a 1.5x 1.5 cm^2 area.

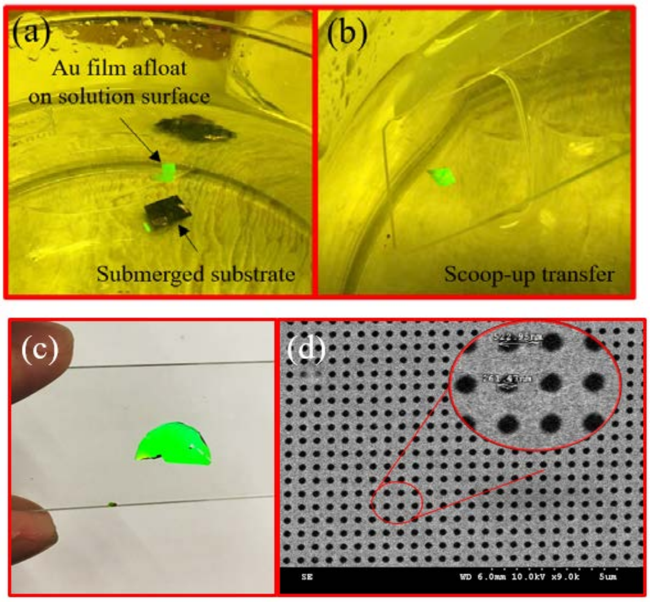

Fig. 2 (a) Peel-off process so that the Au film and the ARC/Si substrate was separated with water assistance, resulting in the Au film afloat on the water surface, (b) scoop-up process for the film's transfer, (c) a photograph of the transferred glass chip, (d) SEM images of gold hole array patterns near the center of a pattern. The inset shows the dimension of the period.

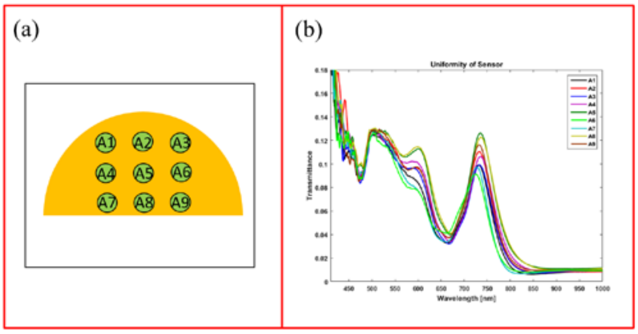

Fig.3 (a) Nine checked spots over a 1.5x1.5 cm2 hole arrays area. Each spot is about 400 µm in diameter. (b) The transmission spectra of A1 to A9 spots.

Finally, based on the performance from the leading experiment, we transferred the structured Au film to fiber ends. By changing surrounding refractive index variations of glucose solutions from 0% (n=1.3333) up to 36% concentration (n=1.3827), the resonance wavelength shifts from the reflectance spectra are seen in Fig. 4(a), and the sensitivity shown in Fig. 4(b) is ~300.71 nm/RIU.

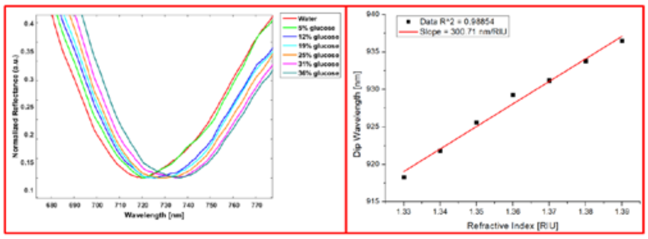

Fig. 4 (a) Wavelength shift responses for 0% to 36% concentration glucose solvents, and (b) the corresponding sensitivity of SPR sensors.

3. Conclusion

A novel peel-off and scoop-up process to make optical fiber sensing probes for surface plasmon resonance sensing has been demonstrated. The process is potentially cost effective and efficient. The reasonably good uniformity of the glass chip and good sensitivity of the fiber probes suggest that the metallic film transferring method has a potential to develop fiber probes for bio or chemical sensing or other broader applications.

Acknowledgements

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